

TABLE I. Sequential treatments of wool fabrics for shrinkage control following a seven-factorial design.

| Experiments (Rows) | Step 1: Pretreatment* | | | | | | Step 2: Treatment |
|-----------------------|----------------------------|-----------------------|---------------------|-------------------|-------------------|---|-------------------------|
| | X1 pH* NaOH (g/L) | X2 Liquor Ratio | X3 time, min. | X4 GA (g/L) | X5 DD (g/L) | X6 H ₂ O ₂ (30% w/v) | X7 Enzyme (% owf) |
| 1 | 1 | 1:20 | 20 | 1 | 3 | 20ml/L | 0 |
| 2 | 3 | 1:20 | 20 | 0 | 0 | 20ml/L | 2 |
| 3 | 1 | 1:30 | 20 | 0 | 3 | 0 | 2 |
| 4 | 3 | 1:30 | 20 | 1 | 0 | 0 | 0 |
| 5 | 1 | 1:20 | 40 | 1 | 0 | 0 | 2 |
| 6 | 3 | 1:20 | 40 | 0 | 3 | 0 | 0 |
| 7 | 1 | 1:30 | 40 | 0 | 0 | 20ml/L | 0 |
| 8 | 3 | 1:30 | 40 | 1 | 3 | 20ml/L | 2 |

*pH range for NaOH: 11.4 to 12.2.

TABLE II. The Physical Properties of Samples Treated in Experiments 1-8 and the Control.

| Experiments (Rows) | Weight loss (%) | Δ Thickness (%) | Δ Regain (%) | Shrink- age (%) | Δ WI (%) | Δ YI (%) | Strength (Kg) |
|-----------------------|--------------------|---------------------------|------------------------|--------------------|--------------------|--------------------|------------------|
| 1 | 1.18 | 31.9 | 10.2 | 9.16 | -4.01 | 0.03 | 20.8 |
| 2 | 22.3 | 0.17 | 7.86 | 5.16 | 144 | -32.5 | 6.40 |
| 3 | 23.1 | 7.65 | 8.52 | 12.4 | 64.1 | -16.5 | 4.50 |
| 4 | 1.73 | 60.0 | 10.3 | 30.6 | -77.4 | 20.9 | 17.3 |
| 5 | 27.0 | -1.74 | 5.37 | 11.6 | 72.9 | -19.6 | 4.80 |
| 6 | 1.72 | 65.6 | 7.62 | 35.7 | -60.4 | 15.1 | 16.9 |
| 7 | 0.56 | 36.9 | 10.9 | 9.27 | 27.6 | -7.40 | 19.8 |
| 8 | 39.0 | -21.4 | 10.6 | -0.86 | 194.7 | -45.9 | 5.20 |
| control | na | na | na | 21.2 | na | na | 20.6 |

TABLE III. Importance of Factors from Treatments 1 to 8 of Table I.

| Factors | Weight loss (%) | Δ Thick- ness (%) | Δ Regain (%) | Relative Shrink- age (%) | Δ White- ness (%) | Δ Yellow- ness (%) | Strength, Maximum Load (Kg) |
|---------|-----------------------|--------------------------------|------------------------|--------------------------------|--------------------------------|---------------------------------|--------------------------------------|
| X1 | 12.9 | 29.6 | 1.42 | 28.2 | 40.4 | 1.15 | -4.10 |
| X2 | 12.2 | -12.7 | 9.24 | -10.2 | 56.5 | -11.9 | -2.10 |
| X3 | 19.9 | -20.4 | -2.50 | -1.60 | 108 | -29.6 | -2.30 |
| X4 | 21.2 | -41.6 | 1.64 | -12.0 | 10.7 | -3.35 | 0.50 |
| X5 | 13.4 | -11.6 | 2.50 | -0.30 | 27.4 | -8.67 | -0.90 |
| X6 | 9.52 | -83.9 | 7.68 | -67.6 | 363 | -85.5 | 8.70 |
| X7 | 106 | -209 | -6.72 | -56.5 | 589 | -143 | -53.9 |

TABLE IV: Area Shrinkage (%) of samples treated in Table I.

| Experiments (Rows) | Initial Shrinkage (%) | Relative Shrinkage (%) | Overall Shrinkage (%) |
|--------------------|--------------------------|---------------------------|--------------------------|
| 1 | 18.3 | 9.16 | 25.8 |
| 2 | 10.7 | 5.16 | 15.3 |
| 3 | 17.9 | 12.4 | 28.1 |
| 4 | 27.7 | 30.6 | 49.8 |
| 5 | 16.6 | 11.6 | 26.3 |
| 6 | 29.8 | 35.7 | 54.9 |
| 7 | 18.5 | 9.27 | 26.1 |
| 8 | 5.04 | -0.86 | 4.22 |
| Control | na | 21.2 | 21.2 |

TABLE V. Treatments without Enzyme, 30°C, 30 minutes.

| Sample | NaOH g/L | Triton X-114 2 g/L | GA g/L | DD g/L | H ₂ O ₂ (30% w/v) |
|--------|--|-----------------------|-----------|-----------|--|
| 61 | 1 | 2 | 1 | 3 | 20 ml/l |
| 79 | 3 | 2 | 1 | 3 | 20 ml/l |
| 101 | Blank: processing conditions without additives | | | | |

TABLE VI. Physical Properties of Fabrics Treated According to Treatments in Table V.

| Sample | Weight loss (%) | Δ Thick-ness (%) | Δ Regain (%) | Relative Shrink-age(%)* | Δ White-ness (%) | Δ Yellow-ness (%) | Strength (Kg) |
|--------|-----------------|-------------------------|---------------------|-------------------------|-------------------------|--------------------------|---------------|
| 61 | 0.60 | 15.3 | 12.30 | 7.34 | 69.5 | -14.7 | 21.6 |
| 79 | 0.94 | 14.6 | 8.20 | 2.95 | 76.6 | -18.4 | 21.4 |
| 101 | 0.08 | 8.64 | -2.34 | 13.7 | 37.7 | -8.06 | 18.8 |

*Initial and overall shrinkages (not shown in Table 6) are as follows: #61 = 7.96% and 14.3%;

#79 = 7.59% and 10.3%; Blank = 6.71% and 19.5%, respectively.

TABLE VII. Enzyme System with PAA/ Triton X-114.

| Pretreatment* (#61) | NaOH 1 g/l | Triton X-114 2g/L | GA 1 g/l | DD 3 g/l | H ₂ O ₂ (30 % w/v) 20ml/l |
|------------------------|---------------|-------------------------|---|-------------|---|
| Treatment (#51) | | | Triton X-114, 1 g/L PAA, 2 % owf No enzyme | | |
| Treatment (#57) | | | Triton X-114, 1 g/L PAA, 2 % owf 1.5 g/L enzyme | | |
| Treatment (#99) | | | Triton X-114, 1 g/L PAA, 2 % owf enzyme, 2.0% owf, together with 2% owf Na ₂ SO ₃ | | |

*Pretreatment #61 was used for PAA/ Triton X114 treatments, #51, #57, and #99.

TABLE VIII. Property Values of Fabrics Treated According to Table VII.

| Sample | Weight Loss, % | Δ Thick-ness | Δ Regain | Shrink-age, % | Δ White-ness | Δ Yellow-ness | Strength (Kg) |
|--------|----------------|---------------------|-----------------|---------------|---------------------|----------------------|---------------|
| 51 | -1.43 | 28.6 | -7.86 | 6.61 | 76.5 | -14.8 | 23.1 |
| 57 | 0.37 | 27.1 | -9.08 | 7.73 | 127 | -23.7 | 21.2 |
| 99 | 5.41 | 26.0 | -11.9 | 1.16 | 205 | -40.8 | 15.0 |
| Blank | -1.34 | 25.9 | -12.3 | 21.9 | 22.6 | -8.34 | 16.6 |

| Sample | Initial Shrinkage, % | Relative Shrinkage, % | Overall Shrinkage, % |
|--------|----------------------|-----------------------|----------------------|
| 51 | 10.7 | 6.61 | 16.6 |
| 57 | 7.44 | 7.73 | 14.6 |
| 99 | 8.88 | 1.16 | 9.94 |
| Blank | 11.3 | 21.9 | 30.7 |

TABLE IX. Central Composite Design for Enzymatic Treatment.

| Run | Na ₂ SO ₃ (% owf) | Enzyme (% owf) | Time (Minutes) |
|-----|---|-------------------|----------------|
| 1 | 0.5 | 0.5 | 30 |
| 2 | 0.5 | 0.5 | 50 |
| 3 | 0.5 | 1.5 | 30 |
| 4 | 0.5 | 1.5 | 50 |
| 5 | 1.5 | 0.5 | 30 |
| 6 | 1.5 | 0.5 | 50 |
| 7 | 1.5 | 1.5 | 30 |
| 8 | 1.5 | 1.5 | 50 |
| 9 | 0.0 | 1.0 | 40 |
| 10 | 2.0 | 1.0 | 40 |
| 11 | 1.0 | 0.0 | 40 |
| 12 | 1.0 | 2.0 | 40 |
| 13+ | 1.0 | 1.0 | 20 |
| 14+ | 1.0 | 1.0 | 60 |
| 15+ | 1.0 | 1.0 | 40 |
| 16+ | 1.0 | 1.0 | 40 |
| 17+ | 1.0 | 1.0 | 40 |
| 18+ | 1.0 | 1.0 | 40 |
| 19+ | 1.0 | 1.0 | 40 |
| 20+ | 1.0 | 1.0 | 40 |
| * | P | Only pretreatment | |
| ** | B | Blank | |
| *** | C | Control, wash/dry | |

*Samples "P" were only pretreated with alkaline peroxide/DD/GA system without further enzymatic treatment for 30 minutes.

**Samples "B" as the blank were pretreated and treated using the same conditions with Run 1-20 but only with water in the treatment bath for 30 minutes.

***Samples "C" were not treated but washed 5 times and air-dried.

+These runs represent the center points for estimating curvature in the construction of the 3D graphs for the central composite design Figure 15.